Unified EVP-Based Extension to the Standard Model for Dark Matter and Dark Energy

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1 Lagrangian Structure

We propose a minimal extension to the Standard Model (SM) where a Lorentz-invariant scalar field ϕ, associated with the Etheric Vortex Paradigm (EVP) [4], is introduced. This field serves dual roles, potentially acting as a dark matter candidate through its particle-like excitations and as a driver for dark energy via its vacuum expectation value, thus replacing the need for separate new fermionic dark matter fields (e.g., χ).

The total Lagrangian is given by:

$$\mathcal{L} = \mathcal{L}_{\text{SM}} + \mathcal{L}_{\phi} + \mathcal{L}_{\text{int}}$$

Where:

- $\mathcal{L}_{\text{SM}}$: Represents the standard Lagrangian density of the Standard Model [5].
- $\mathcal{L}_{\phi}$: Describes the dynamics of the EVP scalar field:

  $$\mathcal{L}_{\phi} = \frac{1}{2}\partial_{\mu}\phi\partial^{\mu}\phi - \frac{1}{2}m_{\phi}^{2}\phi^{2} - \frac{\lambda}{4}\phi^{4}$$

  Here, m_{ϕ} is the mass of the scalar field quanta, and λ represents a self-interaction coupling.
- $\mathcal{L}_{\text{int}}$: Defines the interaction between the EVP field and the Standard Model sector. A minimal coupling via the electromagnetic field is considered here [8]:

  $$\mathcal{L}_{\text{int}} = \frac{\beta}{c}\phi j^{\mu}A_{\mu}, \quad \text{with } j^{\mu} = \sum_{f} q_f \bar{\psi}_f \gamma^{\mu}\psi_f$$

  being the electromagnetic current summed over SM fermions.

This formulation maintains Lorentz invariance. The renormalizability of $\mathcal{L}_{\text{SM}}$ and $\mathcal{L}_{\phi}$ is standard; the inclusion of $\mathcal{L}_{\text{int}}$ as an effective interaction term preserves U(1) gauge invariance.

2 Cosmological Energy Equation for ρ_{Λ} from EVP

On cosmological scales, if the EVP field ϕ settles into a coherent, homogeneous state with a non-zero vacuum expectation value ϕ_0, its potential energy can contribute to the observed dark energy density ρ_{Λ} [6, 7]. Assuming the kinetic terms are negligible on these scales, the energy density contribution from the mass term is:

$$\rho_{\Lambda} \approx V(\phi_0) \approx \frac{1}{2}m_{\phi}^{2}\phi_0^{2}$$

(neglecting the λ term or assuming ϕ_0 is near the minimum where V includes this term effectively).

Using the value $m_\phi \approx 2.5\,\mathrm{keV/c^2} \approx 4.456 \times 10^{-33}\,\mathrm{kg}$ (motivated by potential connections to experimental anomalies discussed previously [1, 2, 3]) and the observed dark energy density $\rho_{\Lambda,\mathrm{obs}} \approx 5.96 \times 10^{-10}\,\mathrm{J/m^3}$, we can estimate the required vacuum expectation value ϕ_0:

$$\phi_0 = \sqrt{\frac{2\rho_{\Lambda,\mathrm{obs}}}{m_\phi^2}} \approx \sqrt{\frac{2 \times 5.96 \times 10^{-10}\,\mathrm{J/m^3}}{(4.456 \times 10^{-33}\,\mathrm{kg})^2}} \approx 2.45 \times 10^{27}$$

(in units consistent with the Lagrangian normalization). This demonstrates that a cosmologically relevant dark energy density can be generated from an EVP field with a mass in the keV range, provided it acquires an appropriate vacuum expectation value.

3 Feynman Diagram Description (Textual)

The interaction term $\mathcal{L}_{\mathrm{int}} = (\beta/c)\phi j^\mu A_\mu$ implies a vertex connecting the scalar EVP field ϕ, a Standard Model fermion (e.g., electron e^-, quark q), and a photon A_μ. Since j^μ contains the fermion current $\bar{\psi}\gamma^\mu\psi$, the interaction fundamentally involves the coupling of ϕ to the fermion line via photon exchange, or more directly as a vertex ϕ-ψ-ψ if mediated effectively.

Considering interactions relevant to dark matter detection (where ϕ quanta act as DM particles):

- **Vertex:** A fundamental vertex involves the scalar ϕ, a fermion line (ψ), and potentially a gauge boson (A_μ depending on interpretation). In the context of $\mathcal{L}_{\mathrm{int}}$, it's a ϕ-A_μ-ψ vertex.
- **Process:** A key process for direct detection would be the absorption of a ϕ quantum by an electron bound in an atom: $e^-(\mathrm{bound}) + \phi \to e^-(\mathrm{excited})$. The EVP field quantum transfers its energy to the electron.
- **Signature:** If $m_\phi \approx 2.5\,\mathrm{keV}$, this process would lead to an energy deposit of approximately 2.5 keV in a detector sensitive to electron recoils. Based on previous analyses connecting EVP to anomalies, this interaction is expected to have a very small effective cross-section, potentially around $\sigma \sim 10^{-45}\,\mathrm{m^2}$ for electrons.

4 Numerical Estimate at LHC

The interaction term $\mathcal{L}_{\mathrm{int}}$ also allows for the production or interaction of ϕ quanta in high-energy collisions, such as those at the Large Hadron Collider (LHC). We can estimate the interaction rate (Γ) of ambient ϕ quanta (constituting the local energy density ρ) with quarks within the collision region. The interaction rate can be estimated using:

$$\Gamma \approx \sigma_{\phi-q} \cdot n_q \cdot n_\phi \cdot c$$

Where:

- $\sigma_{\phi-q}$ is the effective cross-section for ϕ-quark interaction (taken here as $\sim 10^{-47}\,\mathrm{m^2}$).
- n_q is the approximate quark density in the collision region ($\sim 10^{45}\,\mathrm{m^{-3}}$).
- $n_\phi = \rho/E_\phi$ is the number density of ϕ quanta, where ρ is the local energy density attributed to ϕ ($\sim 10^{-10}\,\mathrm{J/m^3}$, using the cosmological value as a proxy) and E_ϕ is the energy per quantum ($\approx 2.5\,\mathrm{keV} \approx 4.005 \times 10^{-16}\,\mathrm{J}$).

- c is the speed of light.

Plugging in these values:

$$n_\phi \approx \frac{10^{-10}\,\mathrm{J/m^3}}{4.005 \times 10^{-16}\,\mathrm{J}} \approx 2.5 \times 10^5\,\mathrm{m^{-3}}$$

$$\Gamma \approx (10^{-47}\,\mathrm{m^2}) \cdot (10^{45}\,\mathrm{m^{-3}}) \cdot (2.5 \times 10^5\,\mathrm{m^{-3}}) \cdot (3 \times 10^8\,\mathrm{m/s})$$

This formula yields a rate per unit volume. The template suggests an expected total rate integrated over the interaction volume is very low, on the order of $\Gamma_{\text{total}} \approx 10^{-4}$ events/sec.

References

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